Refractive Error in Children in Cambodia and Childhood Blindness/Severe Visual Impairment in Sri Lanka

ZOE WEIZHI GAO
MBBS

This thesis is submitted for the Degree of Master of Ophthalmology, Department of Ophthalmology and Visual Sciences, University of Adelaide

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Abstract

This study has two main components with a common theme of paediatric ophthalmology in Asia. The first component aimed to assess the prevalence of refractive error in 12-14 year old children in urban Phnom Penh and rural Kandal Provinces of Cambodia. The prevalence of refractive error in Cambodia has not been previously studied and is important for the planning and implementation of refraction services. Uncorrected refractive error is a leading cause of visual impairment worldwide and can have a dramatic impact on a child’s learning capability. The chief aim of the second component was to determine the major causes of childhood blindness and severe visual impairment in Sri Lanka, in particular those that are avoidable and what public health strategies need to be implemented to address them.

A randomised cluster sample cross-sectional survey of ten schools from Phnom Penh Province and 26 schools from Kandal province was undertaken in October 2010. Random selection of children at each school was used to identify the study sample. Children were examined by teams of Australian and Cambodian optometrists, ophthalmic nurses and ophthalmologists who performed visual acuity (VA) testing and cycloplegic refraction. 5527 children were included in the study. The prevalences of uncorrected, presenting and best-corrected VA ≤ 6/12 in the better eye were 2.48%, 1.90%, and 0.36% respectively. In Phnom Penh Province, the prevalences of uncorrected, presenting and best-corrected VA ≤ 6/12 in the better eye were 5.91%, 4.36% and 0.75% respectively. In Kandal Province, the prevalences of uncorrected, presenting and best-corrected VA ≤ 6/12 in the better eye were 0.51%, 0.51% and 0.14% respectively. Only 43 children presented with glasses whilst a total of 315 glasses were dispensed. The total prevalence of refractive error was 6.57% but
there was a significant difference between urban (13.7%) and rural (2.5%) schools (p value < 0.0001). Refractive error accounted for 82.3% of the visual impaired eyes, cataract for 1.7%, and other causes in 7.1%. Myopia (spherical equivalent of ≤ -0.50D in either eye) affected 5.5% of 12 year old children increasing to 6.0% of 14 year olds. Myopia was associated with increased age, female gender and schooling in urban centres.

Thirteen schools for the blind were visited in Sri Lanka between October 2008 and October 2009 by a team of ophthalmologists and optometrists. Each child’s examination findings were recorded in a standardized World Health Organisation Prevention of Blindness Eye Examination Record for Childhood Blindness Form. Of the 206 children surveyed, 83.5% were blind (BL=Visual acuity [VA] <3/60), and 9.2% had severe visual impairment (SVI=VA <6/60 to 3/60 in the better eye) on presentation. The major anatomical site of BL/SVI was the retina in 35.9% of cases, followed by the whole globe in 22.4% of cases. The major underlying aetiologies of BL/SVI were unknown in 43.75% of cases and hereditary in 37.5%. Avoidable causes of BL/SVI accounted for 34.9% of cases; retinopathy of prematurity made up the largest proportion of this subgroup. The data support the need to develop specialised paediatric ophthalmic services, particularly in the face of advancing neonatal life support in Sri Lanka. One third of the children could have had improved vision with the prescription of an optical device highlighting the need for increased optician services.
DECLARATION

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This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Zoe Gao and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Dr. Zoe Gao (Candidate), Master of Ophthalmology, Adelaide University
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ABBREVIATIONS

BL: Blind

BVA: Best corrected visual acuity

CI: Confidence Interval

D: Dioptres

LVA: Low Vision Aid

NPL: No Light Perception

ROP: Retinopathy of Prematurity

PBL ERCB: Prevention of Blindness Eye Examination Record for Childhood Blindness

PVA: Presenting visual acuity

SVI: Severe visual impairment

TGF-β: Transforming growth factor-β

UVA: Uncorrected visual acuity

VA: Visual acuity

WHO: World Health Organisation
Chapter One

Refractive error in children

Normal Development of the Eye

The normal eye is approximately 17 mm long at birth. It grows rapidly in size during the first years of life, increasing by about 5mm by the age of 6. The rate of growth then slows and increases again at puberty, but usually by only an additional one mm. This growth largely occurs as a result of scleral growth. The cornea, which is relatively large at birth, reaches adult size by 2 years of age. The lens grows rapidly after birth, and continues to grow throughout life.

At birth the eye is hyperopic, but normally undergoes a shift to emmetropia, a process known as emmetropisation. Emmetropia is defined as the refractive state where parallel light rays striking the eye, are refracted so as to converge upon the retina, with the eye in a state of rest. This should be differentiated from the range of refractive states where visual acuity is normal. It is possible to have little visual impairment with mild myopia, and even substantial hyperopia where accommodation can be used to bring the image into focus on the retina. Emmetropisation occurs through both passive and active processes. The passive process involves proportional enlargement of the eye as the child grows. The increase in axial length, lengthening of the radius of curvature of the cornea and lens as well as deepening of the anterior chamber all reduce the dioptric power of the eye. Further increase in the anteroposterior axis can result in myopia, but this is usually prevented by the simultaneous flattening of the lens as growth proceeds. However, if the eyeball continues to grow, the lens can no longer compensate. The active process of emmetropisation involves feedback from the retina and subsequent alterations in axial
length growth. Defective image formation interferes with the feedback and ametropia results.\textsuperscript{5} Recent data have also suggested that the natural end-point of refractive development might actually be mild hyperopia rather than emmetropia.\textsuperscript{4}

**Refractive error**

Refractive error is a leading cause of visual impairment worldwide. If uncorrected, particularly in school-aged children, there is a dramatic impact on learning capability and potential.\textsuperscript{6}

Refractive error occurs when light rays are not brought into focus on the retina. If the images are focused in front of the retina this results in myopia.\textsuperscript{7} If images are focused behind the retina this results in hyperopia. (Figure 1).

![Fig. 1 – A – emmetropia, B – hyperopia, C – myopia](image)

Myopia can occur when the axial length of the eye is relatively greater than the power of the refracting elements. This is called axial myopia. It can also occur due to refractive or index myopia where the refractive power of the eye is relatively greater than the axial
length, for example in keratoconus, where the corneal refractive power is higher, or in nuclear sclerotic cataract, where the lens becomes more dense and increases its refractive power.7

Hyperopia occurs when the eyeball is too short relative to its focal power (axial hyperopia) or if the refractive power of the eye is inadequate. An extreme example of this is aphakia. Astigmatism occurs when the refractive power of the eye varies in different meridians.7

The degree of refractive error is measured based on how many dioptres (D) of lens correction is required to achieve emmetropia. For example, a myopic child will require a minus or concave lens to cause divergence of light rays so that they will no longer focus in front of the retina but on the retina. The power of the lens required to do this is a measure of how myopic that child’s eye is.7 Myopia greater than or equal to -6D is associated with premature cataracts, glaucoma, retinal detachment, and macular degeneration. For these reasons, it is a major cause of blindness.8 High myopia affects 2% of the general population in the United States but there is an estimated prevalence of up to 10% in Asian populations.9,10,11

However, the definitions of myopia, hyperopia and emmetropia are not necessarily uniform across studies and the procedures used to measure refractive status are different. For example, several large population based studies around the world have all used different definitions for refractive error.6 Some studies have defined myopia as less than or equal to -0.5 dioptres spherical equivalent12 whilst others have defined the lower border of myopia to be -0.75 dioptres.13 Some studies have used retinoscopy to measure refractive status whilst other studies have used autorefractors. Other studies have defined refractive error in children with unaided visual acuity that corrects with refraction.14 Given this
discrepancy between studies throughout the world, it can be difficult to compare results. It is also difficult when performing research to decide what definition to choose. Using a different definition can influence the prevalence of refractive error. This is because it is possible for children to have low myopia but very little visual impairment. Therefore, by using a definition of myopia of spherical equivalent -0.5D or more, this is including children with very low myopia and low cylinder who may not actually have any visual impairment. Conversely, by only including children with visual impairment, children with low levels of refractive error will be excluded. This may not be clinically significant at that point in time but children with low refractive error may go on to develop higher refractive error which is important to plan for from a public health perspective in terms of implementing management strategies.

**The Aetiology of Myopia**

It is well recognised now that the development of myopia is related to both genetic and environmental factors.\(^1\)

**Genetics**

Twin studies have shown that there is a genetic component to the development of myopia. Monozygotic twins resemble each other more closely in refractive error and ocular component values compared to dizygotic twins.\(^1\) A parental history of myopia is also a risk factor for the development of myopia. Children with two myopic parents have a prevalence of myopia of 30-40%. With one myopic parent this prevalence drops to 20-25%, and even further to less than 10% with no myopic parent.\(^15\) Furthermore, children with myopic parents have longer axial lengths during the development and growth of the eye even before myopia occurs. Multiple genes have been identified to be associated with myopia and it is thought that the development of myopia is not linked to any one particular gene.
Instead multiple genetic expressions, which interact with multiple environmental factors, result in the development of myopia.¹

**Environmental influences**

It is now recognised that visual input works as a feedback mechanism to influence eye growth aiming for emmetropisation. Refractive errors result from failures in either input or output from this feedback.

Evidence for this feedback mechanism has largely arisen from animal models. Form deprivation and defocus from spectacle lenses are two basic stimuli used in animal myopia research. Degrading the retinal image of monkeys, chickens or tree shrews by suturing the lid shut or by using translucent occluders has been found to result in accelerated axial growth and myopia.¹⁶ This is a local effect mediated by the retina, occurring in area of sclera corresponding to the deprived portion of the visual field, even if the optic nerve is severed.¹⁷ Neonates tend to have the greatest response.¹⁸ Analogous human myopia has been demonstrated after deprivation from cataract.¹

Experiments with positive and negative lenses have also demonstrated the plasticity of the eyeball and the fact that visual input can influence axial growth.¹⁹ These results have raised the possibility of whether spectacle correction of refractive errors can influence further refractive development. However, limited studies have not shown that differing levels of correcting for myopia have any influence in the final refractive status.²⁰,²¹ Management with bifocal²²,²³,²⁴ or multifocal²⁵ spectacles prescribed to reduce accommodative demand in myopes have had generally poor results. Rigid contact lenses have shown some positive results in retarding the progression of myopia.²⁶ Atropine has also been advocated for the treatment of myopia because it prevents the accommodative response. It has shown to
reduce the progression of myopia in limited trials\textsuperscript{25,27} but its widespread use is limited because of the inconvenience of prolonged mydriasis and cycloplegia.

There have also been several epidemiological studies which have shown an association between increased near work and myopia.\textsuperscript{28,29,30} However, there are other studies which have not shown a positive association.\textsuperscript{31} The inconsistency may be related to the reliance on surrogates for the amount of near work such as number of books read per week. This may be an indicator of educational attainment which in itself is independently associated with myopia.\textsuperscript{30} Furthermore, there is growing interest in the idea that increased outdoor activity is associated with a lower rate of myopia, perhaps being a protective factor.\textsuperscript{32,33} There is little in data in humans but animal studies are suggestive that outdoor activity may be protective perhaps because of greater light exposure. These findings support the theory that visual input is linked to emmetropisation of the eyeball.

**The Sclera**

Current theories of the development of emmetropia recognise that scleral growth has a pivotal role in the aetiology of myopia.\textsuperscript{34} The sclera is a tough barrier that supports and anchors various intraocular and extraocular structures. It serves as an attachment point for extraocular muscles and entry/exit points for blood vessels and nerves. It must be able to control eye shape and prevent deformation during eye movements, accommodation and changes in intraocular pressure. This ensures that the vision remains stable and the globe does not rupture.\textsuperscript{34,35} This requires the sclera to be both strong but with a degree of elasticity. Furthermore it must try and retain these properties during remodelling while the eye is growing.\textsuperscript{34} In high myopia, the sclera becomes thinned and extensible. This results in an inability to withstand expansive forces of intraocular pressure and the formation of staphylomas.\textsuperscript{36}
The sclera is a viscoelastic structure that stretches linearly with increased load but returns to its original state when the load is reduced. It also slowly stretches or creeps, in response to a constant load over time.\textsuperscript{37} Experimental studies have shown that different regions of the sclera display different elastic properties and creep rates.\textsuperscript{38} Additionally, the properties change with time, displaying lower creep rates once the eye reaches adulthood.\textsuperscript{39}

In eyes where myopia develops, there is an increase in scleral elasticity.\textsuperscript{36} However, a large proportion of the difference in elasticity can be accounted for by the difference in scleral thickness with myopic eyes having thinner sclera.\textsuperscript{36} Therefore there are other biochemical factors that are important in the development of myopia. Creep rates however, have been shown to be significantly higher, particularly at the posterior pole, in eyes that go on to develop myopia.\textsuperscript{38,39} Unlike elasticity, this was shown to be a significant factor even after scleral thickness was taken into account. This implies that changes in the scleral matrix properties influence the development of myopia.

The sclera is composed of collagen fibrils surrounded by an organised and complex structure of proteoglycans and glycoproteins. This extracellular matrix is enclosed in a lamellar structure of collagen fibril bundles with the scleral fibroblasts that secrete the matrix located between the bundles.\textsuperscript{34,35} In myopia, there is a more layered, lamellar structure to the collagen fibril bundles with thinner collagen fibrils.\textsuperscript{40} Based on animal studies, it has been hypothesised that the retina sends signals to the sclera to alter its matrix.\textsuperscript{34}

Thinning of the sclera in myopia is associated with a general loss of collagen and proteoglycans in defined areas (predominantly the posterior pole).\textsuperscript{41} This demonstrates that
the change is not simply due to tissue redistribution as the sclera stretches with the growth
of the eyeball. The decrease in collagen is largely due to the reduced production of type I
collagen which makes up 99% of the collagen in sclera.41 In addition, the existing tissue is
degraded and eliminated by matrix metalloproteinases.42 The proteoglycan profile follows
a similar course with decreased production and increased degradation in the myopic eye.43

Myofibroblasts may also have a role to play in the development of myopia.
Immunohistochemistry has shown the sclera to contain a subset of cells which express a
protein called alpha-smooth muscle actin which is typically expressed in highly contractile
cells known as myofibroblasts.44 There may even be an age-dependent increase in the
population of these cells. They are derived from fibroblasts and are important in relieving
tension within their tissue matrix by their contractile response. In other tissues, they are
also important in wound healing, contracting wound openings and laying down scar tissue.
After healing is complete, the cells usually undergo apoptosis.34 However, in the sclera it
appears that there is a stable population of the myofibroblasts rather than a transient rise.
One of the important signalling factors for the differentiation of fibroblasts to
myofibroblasts is transforming growth factor-β (TGF-β).45 In myopic eyes, it may be that
TGF-β release is reduced in response to degraded visual inputs from the retina and this
results in a lower population of myofibroblasts. Figure 2 shows a proposed mechanism for
the development of myopia at a biochemical and cellular level.
Figure 2. Flowchart of proposed model of scleral remodelling in the development of myopia.34

The above model of the underlying biochemical scleral remodelling in the development of myopia illustrates that the prevention of this aberrant remodelling, perhaps through TGF-β, may be an option for the long term therapy in preventing high myopia and its visual consequences.
**Current Epidemiological Data**

Worldwide, there are about 12 million children below the age of 15 years with uncorrected refractive errors resulting in avoidable visual impairment. Refractive error is therefore one of the major targets for the “Vision 2020: Right to Sight” Initiatives. It aims to:

1. Create awareness and demand for refractive services through community-based services/primary eye care and school screening.
2. Develop accessible refractive services for individuals identified with significant refractive errors. This will require training in refraction and dispensing for paramedical eye workers, if ophthalmologists and/or refractionists are not available in sufficient numbers.
3. Ensure that optical services provide affordable spectacles for individuals with significant refractive errors.
4. Develop and make available low vision services and optical devices for all those in need, including children in blind schools or integrated education. Certain low vision devices can be manufactured locally, or purchased externally in bulk supplies to reduce costs.
5. Include the provision of comprehensive low vision care as an integral part of national programmes for the prevention of blindness, or rehabilitative services for the visually disabled.

Myopia places a substantial burden on society and the individual. The annual cost of myopia in the US, based on an overall prevalence of 25%, in terms of eye examinations and prescription of corrective lenses as well as indirect costs of days of lost work and time spent obtaining care, is in the region of US$4.6 billion. This is not taking into account other pathology associated with myopia such as glaucoma, retinal detachment and macular degeneration which have a significant role in permanent visual loss and further health care
costs. Considering the rate of myopia is substantially higher in some South East Asian countries – as high as 80% at the time of graduation from high school in Singapore\textsuperscript{11}, and the fact that myopia is becoming more common\textsuperscript{49}, it is clear that management strategies are required to combat this growing problem. If it could be prevented, this would be an even more economical solution.

Large scale population based surveys in several South-east Asian countries such as Nepal\textsuperscript{50}, India\textsuperscript{51,52}, China\textsuperscript{53} and Malaysia\textsuperscript{54} have been conducted recently using a standardised protocol. In all surveys myopia was defined as -0.5D or less and hyperopia as 2.0D or greater. All children had visual acuity measurements and cycloplegic retinoscopy and autorefraction. Children with visual acuity less than or equal to 6/9.5 underwent subjective refraction.

In Nepal, the prevalence of myopia was 1.2%. The prevalence of hyperopia was 1.4%.\textsuperscript{50} In rural India, the prevalence of myopia was similarly low at 1.4%. The prevalence of hyperopia was 0.8%.\textsuperscript{51} In the survey conducted in urban New Delhi, the prevalence of refractive error was higher with myopia prevalence being 7.4% and hyperopia 7.7%.\textsuperscript{52} In the Shunyi district of China, myopia was essentially absent in 5-year-old children but increased to 36.7% in males, and 55.0% in females. Hyperopia decreased from 8.8% to <2% in males, and from 19.6% to <2% in females with increasing age.\textsuperscript{53} Finally, in Malaysia, myopia prevalence was 9.8% in 7 year olds but this increased to 34.4% in 15 year olds. Hyperopia rates decreased from 3.8% in 7-years-olds to less than 1% in 15 year olds.\textsuperscript{54} In all surveys, myopia was associated with increasing age. However, the significant difference in the prevalence of myopia between the countries shows that race/ethnicity is an associated factor in the development of myopia. In fact, in the Malaysian survey,
myopia was associated with Chinese compared to Malay ethnicity.\textsuperscript{54} The extent to which the difference is due to genetic or environmental influences is difficult to assess.

Another school-based survey of 2400 thirteen- to seventeen-year-old children from junior schools in Yangxi County of China found the prevalence of myopia was 36.8\% in 13-year-olds and this increased to 53.9\% in the 17-year-old population.\textsuperscript{55} Furthermore, they found that myopia was associated with older age, female gender, schooling in the urban versus rural centre and higher parental education.\textsuperscript{55}

One common feature of all the large scale surveys was that spectacle correction was not adequate, particularly in rural areas. There are a number of probable reasons for this, including lack of parental awareness of the problem, concerns that wearing glasses can cause myopic progression, cultural issues about spectacle wear, cost and other socioeconomic factors.\textsuperscript{56}

In Australia, a large study examining over 2000 predominantly 12-year-olds between 2004 and 2005 found that the prevalence of myopia was significantly higher in children of East Asian descent (41.6\%) compared to Caucasians (5.1\%); 19\% of the children wore spectacles and this was associated with female gender and East Asian ethnicity. But 38.3\% of the children who were prescribed glasses had no significant refractive error in either eye. These children were more likely to have parents from a lower socioeconomic group and education and they had a significantly higher prevalence of eyestrain, headache and learning difficulty which may have influenced the prescription of spectacles.\textsuperscript{57}
A similar study in 6-year-old Australian children found the prevalence of myopia was even lower: 1.4%. Again 33.8% of all children with spectacles had been prescribed these in absence of visual impairment, significant refractive error, or amblyogenic factor.

References


Chapter Two

Childhood blindness

Global blindness

The World Health Organisation (WHO) defines blindness as presenting visual acuity (VA) less than 3/60 in the better eye. Moderate visual impairment is defined as a VA of less than 6/18 in the better eye, with severe visual impairment being <6/60 to 3/60. There are an estimated 45 million blind people worldwide and 314 million visually impaired.

The majority of the world’s visually impaired are older adults, with 82% of the world’s blind population 50 years or older despite the fact that they only represent 19% of the world’s population. Females are at higher risk in every age group and every part of the world; 87% of the world's visually impaired live in developing countries and about 75% of blindness and 85% of all visual impairment is avoidable.

Cataract remains the leading cause of blindness globally, followed by uncorrected refractive error, glaucoma and age-related macular degeneration. As health strategies to target infectious diseases have been implemented, such as immunisation programs, the number of people blinded by infectious diseases has been greatly reduced, but age-related impairment is increasing. With longer life expectancies, conditions such as cataract and glaucoma are becoming an increasing problem. This is true for both developing and developed countries. In addition, refractive error such as high myopia, even if corrected, is a risk for premature cataract, glaucoma, macular degeneration and retinal detachment – all additional causes for blindness or visual impairment. Other major causes of blindness
include corneal opacities, diabetic retinopathy, blinding trachoma, retinopathy of prematurity and vitamin A deficiency.²

**Childhood blindness in South-east Asia**

There is an estimated 1.4 million blind children worldwide.² Childhood blindness is a priority of “Vision 2020 – the Right to Sight”, a WHO initiative for the elimination of avoidable blindness. Whilst childhood blindness makes up only a small proportion of the worldwide total of 45 million blind people, it is significant for several reasons. Firstly, children have a lifetime of blindness ahead which affects their ability to obtain an education, employment and earning potential. This secondarily has a significant effect on the child’s family and community.² Secondly, blind children have a higher mortality rate. In developing countries, 60% of blind children are thought to die within a year of becoming blind.⁴ Finally, almost half of blindness in children is avoidable.⁵

Three quarters of the world’s blind children live in developing countries, and two thirds of the blind children live in Asia.⁶ The prevalence of childhood blindness varies from 3/10 000 in affluent societies to 15/10 000 in the poorest communities.⁷ Childhood blindness has a much higher prevalence in developing countries for several reasons. Firstly, in some developing countries, potentially blinding conditions such as vitamin A deficiency, which do not occur in affluent societies, are prevalent there. Harmful traditional eye remedies are also practised. Secondly, preventative measures such as immunisation programs against measles and rubella are often inadequate. Thirdly, specialised services and personnel are lacking for managing conditions requiring surgery.⁸

In addition to the world’s children who are blind, there are an even larger proportion of children with low vision. It has been estimated that the global prevalence of paediatric low
vision is over 10 times that of paediatric blindness, with 7 million children worldwide with low vision due to ocular disease and a further 10 million children worldwide with low vision due to uncorrected refractive error.\textsuperscript{9} Children with low vision are those who after optical correction and surgical treatment have a VA between 6/12 and light perception in the better eye, or a visual field of less than 10° from the point of fixation, but who use or have the potential to use vision for the planning and/or execution of tasks. The majority of these children have retinal lesions or amblyopia but it is possible to restore their ability to perform daily tasks like reading with appropriate low vision services.\textsuperscript{9}

Children under the age of 5 years need targeting not because it is the age group with the highest incidence of blindness, but also because early treatment is required to prevent amblyopia.

Major priorities of the Vision 2020: Right to Sight Initiative\textsuperscript{10} include:

- Elimination of vitamin A deficiency and measles and the resultant corneal scarring
- Specialised tertiary level care facilities for the treatment of cataract and glaucoma
- Screening for retinopathy of prematurity
- Correction with spectacles for refractive errors
- Low vision services for children with incurable visual loss

Control of Vitamin A deficiency includes promotion of breast feeding, home gardening, control of diarrhoea, fortification of food, education about nutrition, and intermittent supplementation with high dose vitamin A.\textsuperscript{10}
Vision 2020 aims to have at least one trained paediatric ophthalmologist for every 10 million population. It aims to reduce the global prevalence of blindness in children from 7/10 000 to 4/10 000.¹⁰

**Childhood blindness in Australia**

In developed countries such as Australia, unavoidable causes of blindness predominate with hereditary retinal dystrophies, disorders of the central nervous system and congenital anomalies being the major causes.⁷ Primary health care, immunisation programs, tertiary level paediatric ophthalmology services, optical and low vision services are all well established. To combat the major unavoidable causes of childhood blindness in Australia, further research into their aetiology and treatment options is required.⁸
References


Chapter Three

Refractive Error in School children in an Urban and Rural Setting in Cambodia

Zoe Gao MBBS\textsuperscript{1,2}, Ngy Meng MD\textsuperscript{3}, James Muecke FRANZCO\textsuperscript{1, 2}, Weng Onn Chan MBChB\textsuperscript{1}, Horm Piseth MA Optom\textsuperscript{4}, Aimee Kong B. Optom\textsuperscript{1}, Theresa Jnguyenphamhh B. Optom\textsuperscript{1}, Yalda Dehghan B. Optom\textsuperscript{1}, Dinesh Selva FRACS, FRANZCO\textsuperscript{1,2}, Robert Casson FRANZCO, PhD\textsuperscript{1,2}, Kim Ang MD\textsuperscript{5}

\textsuperscript{1} Sight For All Foundation, South Australian Institute of Ophthalmology, Adelaide, Australia
\textsuperscript{2} Discipline of Ophthalmology & Visual Sciences, University of Adelaide, Australia
\textsuperscript{3} Preah Ang Doung National Hospital, Phnom Penh, Cambodia
\textsuperscript{4} Fred Hollows Foundation, Australia
\textsuperscript{5} National Paediatric Hospital, Phnom Penh, Cambodia

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STATEMENT OF AUTHORSHIP

Refractive Error in Schoolchildren in an Urban and Rural Setting in Cambodia

Ophthalmic Epidemiology; 2011: accepted paper

Zoe Gao (Candidate) Master of Ophthalmology, Adelaide University
Conception and design of study, acquisition of data, analysis and interpretation of data, drafting of the manuscript, critical revision of the manuscript.

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J Muecke
Contributed to conception and design of the study; training, critical revisions of manuscript; obtaining funding and supervision.

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**W O Chan**
Statistical expertise in the analysis of data, critical revisions of manuscript

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**H Piseth**
Contributed to conception and design of study; acquisition of data

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T Jnguyenphamhh
Contributed to conception and design of study; acquisition of data

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Y Dehghan
Contributed to conception and design of study; acquisition of data

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D Selva
Contributed to conception and design of the study; critical revision of the manuscript for important intellectual content; obtaining funding and supervision.

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RJ Casson
Contributed to conception and design of the study; analysis and interpretation of data; critical revision of the manuscript for important intellectual content; statistical expertise; administrative and technical support; obtaining funding and supervision.

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INTRODUCTION

Uncorrected refractive error is the most common cause of visual impairment in school-aged children both in industrialised and developing countries.\textsuperscript{1} It has a dramatic impact on learning capability and educational potential and hence on a child’s future. In addition, it is also a treatable and therefore avoidable cause of visual impairment.

The prevalence of myopia is increasing dramatically in certain Asian regions and has been most well characterised in individuals of Chinese descent.\textsuperscript{2,3,4} The gene/environment interaction which cause myopia, however, remains unclear. Urban living has emerged as a major environmental factor associated with the development of myopia. This has been demonstrated in surveys from several countries that have compared refractive error between children in urban and rural areas.\textsuperscript{5,6,7,8} A tendency for less academically rigorous classes and lower educational pressures in rural areas, leading to reduced near work, possibly explains the lower prevalence of myopia.\textsuperscript{9} However, the data regarding the associations between near work and outdoor activities and the development of myopia have not always been consistent.\textsuperscript{5,10,11,12,13,14,15}

Cambodia is one of the poorest country in Southeast Asia and has the worst health indicators: the under-5-child mortality rate is 12\% and average life expectancy from birth is 52 years.\textsuperscript{16} The major causes of low vision are uncorrected refractive error (49.8\%) and cataract (42.7\%).\textsuperscript{17} However, currently, there are inadequate data available concerning the prevalence of refractive error in children in Cambodia, the sex and age variation, and refractive coverage. In addition, the prevalence of refractive error in Khmer people has not been previously studied.
In order to compare surveys performed in different countries, a standardised protocol for childhood refractive error evaluation, the Refractive Error Study in Children (RESC) Protocol, was developed\(^\text{18}\) and used in Nepal\(^\text{19}\), Chile\(^\text{20}\), and China.\(^\text{21}\) In this study we aimed to determine the prevalence of refractive error in a previously unstudied ethnic group of school children guided by the international standardised protocol.

**METHODS**

**Sample selection**

Stratified cluster sampling was used to select the study sample. The sampling frame was constructed through data from the Ministry of Education of the schools in Phnom Penh Province, which was considered urban and Kandal Province, which was considered rural. Phnom Penh Province lies in the south-central region of Cambodia and is completely surrounded by Kandal Province. The Ministry of Education only provides data from State schools and therefore private schools were not included in this study.

From the Ministry of Education data, there were a total of 162,941 middle school age children (12-14 years old) in the whole of Cambodia. In Kandal province, there were 17,329 children and in Phnom Penh province there were 13,967 children. There were 145 middle schools in Kandal province which equates to 120 children on average per school. In Phnom Penh province, there were 47 middle schools; hence on average 298 children per school.

Based on previous refractive error surveys,\(^\text{18,22,26}\) the sample size was based on an estimated mean prevalence of refractive error in the 12-14 year old age group of 8%. With
a 20% error bound with 95% confidence, the sample size requirement with simple random sampling was calculated to be 1100 students in each age group. With no oversampling at any particular age, and assuming a uniform age distribution across the 3-year age interval, a total of 3300 children were required. After adjusting for 25% absenteeism and allowing for a 25% increase in sample size due to design effect based on experience from previous refractive error studies\textsuperscript{18}, the sample size requirement increased to 5157 children. Then, for proportionate stratified sampling, we required 45% of the children to be from an urban school.

Based on the average number of children per school in Phnom Penh province and taking into account the absentee rate, with the aim of sampling 2301 children in total, we randomly selected 10 schools to be visited. Accordingly, 26 schools from Kandal Province were selected. At each school in Phnom Penh Province, an equal number of grade 7, 8 and 9 classes were randomly selected until approximately 300 children were sampled at each school. Similarly, at the schools in Kandal Province, classes were randomly selected to achieve a sample size of 120 children at each school.

**Informed consent and Ethics Approval**

Ethics approval was obtained from the Royal Adelaide Hospital Research Ethics Committee in Australia and the National Ethics Committee for Health Research at the Ministry of Education in Cambodia.

Given the logistical difficulty of obtaining consent from each individual student’s parents, consent was obtained from the principal of each participating school prior to commencing the study. Given that the principal at the school was serving as the children’s guardian at the time of the study, they were acting as their legally authorised representative to be able
to give informed consent. Once at the school, each child in the study was informed of the
study via the local Cambodian ophthalmologists in the teams and given the option of not
participating. Before both screening and definitive examinations, the study was explained
in detail to all potential participants.

The study was performed according to the principles of Good Clinical Practice (GCP)
[Chapter 2 of the ICH Harmonized Tripartite Guideline for GCP], the declaration of
Helsinki, and national laws and regulations about clinical studies.

Ocular examination

Examinations were performed by three clinical teams each comprising one Australian
optometrist, three Cambodian refractionists, one Cambodian ophthalmic nurse and one
Cambodian ophthalmologist. In addition, one Australian ophthalmology trainee rotated
between the three different teams to ensure that each team was consistent for quality
control purposes.

Study staff underwent training for familiarization with the study protocol, equipment use,
measurement methods, and data collection forms. The examinations took place over a two-
week period in October 2010 at temporary stations set up in each school while classes were
in session. The testing and examination protocol included lensometry, visual acuity
measurements, cycloplegic retinoscopy and subjective refraction.

Each child was registered with a number allocated to them and a data sheet form with their
name and date of birth, school number and Province recorded.
Distance visual acuity was measured with a logMAR chart (Precision Vision, La Salle, IL, USA), with five tumbling “E” optotypes on each line. Visual acuity measurements began at a distance of 4 meters with the top line (6/60, 20/200). If the orientation of at least four of the five optotypes was correctly identified, the child was then tested by dropping down to line 4 (6/30, 20/100). If one or less optotypes was missed, the testing resumed at line 7 (6/15, 20/50), continuing to line 10 (6/7.5, 20/25) and finally line 11 (6/6, 20/20). If at any level the child failed to recognise four of the five optotypes, the line immediately above the failed line was tested, until successful.

If the top line at 4 meters was missed, the child was advanced to 1 metre with progression down the chart as described above. The lowest line read successfully was assigned as the visual acuity for the eye undergoing testing. The right eye was tested first, then the left eye, each time occluding the fellow eye. The children were requested to indicate the direction of the E optotype either by pointing with his/her hand or by calling the direction. The children were observed to prevent squinting (pinhole effect) while reading the optotypes. If a child presented with glasses, the power of the lenses was measured using a lensometer. For these children, visual acuity was measured first with their glasses – presenting visual acuity (PVA), and then without – uncorrected visual acuity (UVA).

All children had both pupils dilated. Two drops of cyclopentolate 1% were administered 5 minutes apart to each eye. After 20 minutes, if a pupillary light reflex was still present, a third drop was administered. The light reflex and pupil dilation were checked after an additional 15 minutes. Dilating and light reflex status were recorded between 40 to 60 minutes after the first drop. Cycloplegia was considered complete if the pupil dilated to 6 mm or greater and a light reflex was absent. In a very small number of children (less than
1%), cyclopentolate was not sufficient in achieving dilation and cycloplegia and these were excluded from the study.

Cycloplegic refraction was performed using a streak retinoscope in a semidark room. The spherical and cylindrical power and axis necessary to neutralize the shadow movement were noted, first for the right eye and then the left eye. Subjective refraction was performed on children with an uncorrected visual acuity of 6/12 or worse, using retinoscopy values as a starting reference.

Arrangements were made for dispensing spectacles at no cost to the patient. Spectacles were dispensed to those children who had refractive error and had a better best corrected visual acuity during the subjective refraction of 2 lines or more compared to their presenting visual acuity. Children with decreased vision unexplained by refractive error were seen by the local ophthalmologist who performed examination with a hand-held slit lamp and direct opthalmoscope. They were also referred for formal assessment at Preah Ang Doung Hospital in Phnom Penh.

In addition, every tenth child had their vision and retinoscopy performed twice by two independent examiners for quality control purposes.

**Data Analysis**

All data were recorded on a standardised reporting form and data was entered into a Microsoft Excel database. Data were double checked on the day of entry by the Australian optometrist on each team and any unusual or spurious results were rechecked. A double entry method of data verification was not employed but the data were visually checked to ensure that the transcription process was correct. In addition, the data were validated by
range checks on the variables and outliers rechecked for possible data entry errors. The data was analysed using a commercially available statistical package STATA 10.0. Visual acuity was categorised into normal/near normal (VA\(\geq 6/9.5\)), mild visual impairment (VA \(\leq 6/12 \text{ - } \geq 6/19\)), moderate visual impairment (VA \(\leq 6/24 \text{ - } \geq 6/60\)), severe visual impairment (VA < 6/60 – 1/18) and blindness (VA < 1/18) based on the better eye. This is similar to VA categories used previously.\(^7\)

Myopia was defined as spherical equivalent of at least -0.50 D, Hyperopia as +2.00 D or more and astigmatism of -0.75 D of cylinder or more. Children were considered myopic if one or both eyes were myopic, and hyperopic if one or both eyes were hyperopic, as long as neither eye was myopic. Astigmatism was considered separately.

Amblyopia was considered the cause of impairment in eyes with best-corrected VA \(\leq 6/12\) and no apparent organic lesion if one or more of the following criteria were met:

1) esotropia, exotropia or vertical tropia at 4 m fixation or exotropia or vertical tropia at 0.5m
2) anisometropia of 2.00 D or more
3) bilateral ametropia of at least +6.00 D

These criteria are similar to other refractive error studies in children.\(^8,18\)

RESULTS

Study Population

A total of 6156 children were registered for the study. However, some children did not complete the study. After excluding children with incomplete data, and children who
participated but were not aged 12-14, there was a total of 5527 children included in the study analysis (89.8% of the eligible population). This response rate did not differ significantly between urban and rural schools.

There was a preponderance of female children with 3016 (54.6%) of the 5527 total being female versus 2511 (45.4%) being male; 3081 children were from Kandal Province and 2446 from Phnom Penh Province. Due to the random selection process, there were three schools in Phnom Penh Province that were geographically on the border of the Province and it was clear to the survey team that it was not an urban school. The surrounding area was undeveloped and the school’s facilities were very similar to the rural schools in Kandal Province. These three schools were therefore classified as rural prior to data collection. Therefore, there were 3531 rural children and 1996 urban children.

Table 1.1 shows the breakdown of the children’s demographic details based on urban or rural location.

<table>
<thead>
<tr>
<th></th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Age (Year)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>1129</td>
<td>32.0%</td>
</tr>
<tr>
<td>13</td>
<td>1257</td>
<td>35.6%</td>
</tr>
<tr>
<td>14</td>
<td>1145</td>
<td>32.4%</td>
</tr>
<tr>
<td>Total</td>
<td>3531</td>
<td>100%</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1949</td>
<td>55.2%</td>
</tr>
<tr>
<td>Male</td>
<td>1582</td>
<td>44.8%</td>
</tr>
<tr>
<td>Total</td>
<td>3531</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table 1.1. Demographic details of Cambodian study population
Visual acuity

Table 1.2 shows the breakdown of presenting visual acuity (PVA), uncorrected visual acuity (UVA) and best corrected visual acuity (BVA) in the better eye.

<table>
<thead>
<tr>
<th></th>
<th>PVA better eye [N (%; 95%CI)]</th>
<th>UVA better eye [N (%; 95%CI)]</th>
<th>BVA better eye [N (%; 95%CI)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal/near normal</td>
<td>5420 (98.1; 97.7-98.9)</td>
<td>5390 (97.5; 97.0-98.6)</td>
<td>5505 (99.6; 99.5-99.8)</td>
</tr>
<tr>
<td>Mild impairment</td>
<td>77 (1.4; 0.7-1.8)</td>
<td>96 (1.7; 0.9-2.2)</td>
<td>18 (0.3; 0.2-0.4)</td>
</tr>
<tr>
<td>Mod impairment</td>
<td>26 (0.5; 0.3-0.6)</td>
<td>37 (0.7; 0.4-0.8)</td>
<td>1 (0.02; -0.01-0.05)</td>
</tr>
<tr>
<td>Severe impairment</td>
<td>0</td>
<td>1 (0.02; -0.01-0.05)</td>
<td>0</td>
</tr>
<tr>
<td>Blind</td>
<td>2 (0.04; -0.03-0.1)</td>
<td>3 (0.05; -0.01-1.1)</td>
<td>1 (0.02; -0.01-0.05)</td>
</tr>
<tr>
<td>Missing</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Total impairment</td>
<td>105</td>
<td>137</td>
<td>18</td>
</tr>
</tbody>
</table>

Table 1.2. PVA = Presenting visual acuity in the better eye, UVA = Uncorrected visual acuity in the better eye, BVA = Best corrected visual acuity in the better eye. N = number of children, % with 95% confidence interval

The majority of children (98.1%) presented with visual acuity of normal/near normal in the better eye. 105 children had visual impairment in the better eye, with 2 children that were blind – one of which was due to refractive error and was corrected with spectacles. The other child had congenital motor nystagmus.

There were 137 children with uncorrected visual impairment or blindness in the better eye, which is higher than the number of children with presenting visual impairment or blindness in the better eye due to the fact that some children did present with spectacles. However, only 43 (31.4%) children presented with glasses and all these children were from urban schools. There were some children in this group where the spectacle correction was not up to date.
There were 20 children that despite best corrected vision in the better eye were still visually impaired. These cases were due to amblyopia (6), traumatic cataract/retinal damage (1), suspected retinitis pigmentosa (2), congenital motor nystagmus (1) and unexplained causes – those presenting with no pathologic signs and not satisfying criteria for amblyopia (10).

Of the 105 children with presenting visual impairment or blindness in the better eye, 95 (90.5%) could be improved with spectacles; based on presenting VA alone 52 (54.7%) children were without the necessary corrective spectacles. However, many more children with visual impairment in one eye only also required spectacles: 315 spectacles were dispensed in total. As outlined in the methods, spectacles were provided for children who displayed an improvement in visual acuity during subjective refraction.

**Refractive error**

The prevalence of refractive error in urban schools was 13.7% compared to 2.5% in rural schools (p < 0.001; Mann-Whitney test).

The breakdown of refractive error into myopia, hyperopia and astigmatism based on gender and urban versus rural schools is shown in Table 1.3. Table 1.4 shows a comparison of rural versus urban children with breakdown of refractive error by gender and age.
### Table 1.3. Prevalence of Ametropia by Age, Sex and School location; CI = confidence interval

<table>
<thead>
<tr>
<th>Sex</th>
<th>Age</th>
<th>Refractive error either eye</th>
<th>Prevalence (%; 95% CI)</th>
<th>Count</th>
<th>Prevalence (%; 95% CI)</th>
<th>Count</th>
<th>Prevalence (%; 95% CI)</th>
<th>Count</th>
<th>Prevalence (%; 95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>12</td>
<td>Nil</td>
<td>6.5; 3.8-7.3</td>
<td>196</td>
<td>0.9; 0.6-1.1</td>
<td>27</td>
<td>0.6; 0.3-0.8</td>
<td>85</td>
<td>3.4; 2.3-4.1</td>
</tr>
<tr>
<td>Male</td>
<td>12</td>
<td>Nil</td>
<td>5.0; 2.6-5.8</td>
<td>126</td>
<td>0.6; 0.3-0.8</td>
<td>14</td>
<td>0.2-0.6</td>
<td>71</td>
<td>2.0; 1.4-2.6</td>
</tr>
<tr>
<td>Rural</td>
<td>12</td>
<td>2.2; 1.3-2.3</td>
<td></td>
<td>76</td>
<td>0.4; 0.2-0.6</td>
<td>14</td>
<td>0.1-1.7</td>
<td>137</td>
<td>6.9; 4.8-8.9</td>
</tr>
<tr>
<td>Urban</td>
<td>12</td>
<td>12.3; 6.4-16.4</td>
<td></td>
<td>246</td>
<td>1.4; 0.1-1.7</td>
<td>27</td>
<td>0.7; 0.4-1.0</td>
<td>132</td>
<td>6.9; 4.8-8.9</td>
</tr>
<tr>
<td>Female</td>
<td>13</td>
<td>6.0; 3.3-6.7</td>
<td></td>
<td>168</td>
<td>0.7; 0.4-0.9</td>
<td>14</td>
<td>0.8; 0.3-1.3</td>
<td>51</td>
<td>3.4; 2.2-4.3</td>
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<tr>
<td>Male</td>
<td>13</td>
<td>6.0; 3.3-6.7</td>
<td></td>
<td>168</td>
<td>0.7; 0.4-0.9</td>
<td>14</td>
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<td></td>
<td>168</td>
<td>0.7; 0.4-0.9</td>
<td>14</td>
<td>0.8; 0.3-1.3</td>
<td>51</td>
<td>3.4; 2.2-4.3</td>
</tr>
<tr>
<td>Urban</td>
<td>14</td>
<td>6.0; 3.3-6.7</td>
<td></td>
<td>168</td>
<td>0.7; 0.4-0.9</td>
<td>14</td>
<td>0.8; 0.3-1.3</td>
<td>51</td>
<td>3.4; 2.2-4.3</td>
</tr>
<tr>
<td>Female</td>
<td>Total</td>
<td>866</td>
<td>5.8; 3.1-6.8</td>
<td>322</td>
<td>0.7; 0.4-1.0</td>
<td>41</td>
<td>0.7; 0.4-1.0</td>
<td>208</td>
<td>3.8; 2.9-4.5</td>
</tr>
<tr>
<td>Male</td>
<td>Total</td>
<td>866</td>
<td>5.8; 3.1-6.8</td>
<td>322</td>
<td>0.7; 0.4-1.0</td>
<td>41</td>
<td>0.7; 0.4-1.0</td>
<td>208</td>
<td>3.8; 2.9-4.5</td>
</tr>
</tbody>
</table>

Table 1.3. Prevalence of Ametropia by Age, Sex and School location; CI = confidence interval

### Table 1.4. Breakdown of refractive error by urban versus rural location, gender and age

<table>
<thead>
<tr>
<th>Age</th>
<th>Urban</th>
<th>Female</th>
<th>Male</th>
<th>Rural</th>
<th>Female</th>
<th>Male</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Refractive error either eye</td>
<td>Refractive error either eye</td>
<td>Refractive error either eye</td>
<td>Refractive error either eye</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nil</td>
<td>M</td>
<td>H</td>
<td>A</td>
<td>Nil</td>
<td>M</td>
</tr>
<tr>
<td>12</td>
<td>391</td>
<td>46</td>
<td>6</td>
<td>18</td>
<td>371</td>
<td>40</td>
</tr>
<tr>
<td>13</td>
<td>332</td>
<td>61</td>
<td>9</td>
<td>13</td>
<td>287</td>
<td>23</td>
</tr>
<tr>
<td>14</td>
<td>143</td>
<td>35</td>
<td>4</td>
<td>9</td>
<td>145</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>866</td>
<td>142</td>
<td>19</td>
<td>40</td>
<td>803</td>
<td>85</td>
</tr>
</tbody>
</table>

Table 1.4. Breakdown of refractive error by urban versus rural location, gender and age

M = Myopia, H = Hyperopia, A = Astigmatism

In multivariate logistic regression, adjusting for the study design, myopia was significantly associated with age, gender and school location. Females had a higher prevalence of myopia and the prevalence of myopia increased with age. Urban schooling was associated with a higher prevalence of myopia. (Table 1.5)
Refractive Error in Children in Cambodia and Childhood Blindness/Severe Visual Impairment in Sri Lanka

<table>
<thead>
<tr>
<th></th>
<th>Odds Ratio (adjusted)</th>
<th>95% CI</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (Female)</td>
<td>1.43</td>
<td>0.61-0.82</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Age</td>
<td>1.35</td>
<td>1.19-1.53</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Urban</td>
<td>7.80</td>
<td>4.66-12.99</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Table 1.5. Multivariate logistic regression

Cause of Visual Impairment

Refractive error was the cause of visual impairment in almost all cases. 226 children had uncorrected visual impairment in one or both eyes. 181 (80.0%) were due to refractive error. Table 1.6 shows the causes of uncorrected VA of 6/12 or worse in both left and right eyes.

There were several cases of traumatic cataract or corneal scarring causing unilateral visual impairment and 2 suspected cases of retinitis pigmentosa resulting in bilateral visual impairment.
<table>
<thead>
<tr>
<th>Cause</th>
<th>Eyes with UVA 6/12 or worse</th>
<th>Children with UVA 6/12 or worse in one or both eyes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right eye (N, %)</td>
<td>Left eye (N, %)</td>
</tr>
<tr>
<td>Refractive error</td>
<td>152 (81.2)</td>
<td>146 (83.4)</td>
</tr>
<tr>
<td>Amblyopia</td>
<td>15 (8.0)</td>
<td>14 (8.0)</td>
</tr>
<tr>
<td>Cataract</td>
<td>5 (2.7)</td>
<td>1 (0.6)</td>
</tr>
<tr>
<td>Retinal</td>
<td>2 (1.1)</td>
<td>1 (0.6)</td>
</tr>
<tr>
<td>Cornea</td>
<td>2 (1.1)</td>
<td>1 (0.6)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (0.5)</td>
<td>1 (0.6)</td>
</tr>
<tr>
<td>Unexplained</td>
<td>10 (5.3)</td>
<td>10 (5.7)</td>
</tr>
<tr>
<td>Total</td>
<td>187</td>
<td>175</td>
</tr>
</tbody>
</table>

Table 1.6. Causes of uncorrected VA 6/12 or worse

Quality Control

All examination data was performed twice on every tenth child. There were strong agreement between observers for visual acuity and retinoscopic findings. The Cohen’s Kappa and Intraclass correlation coefficient was 0.965 and 0.924 respectively.

DISCUSSION

This study aims to provide an estimate of the prevalence of refractive error and visual impairment in children aged between 12 and 14 in Cambodia. The findings indicate that the prevalence of myopia is low. Estimates of the prevalence of myopia in different ethnic groups are available from a number of studies. The prevalence in Caucasian populations has been estimated in the United States\textsuperscript{22} and Australia.\textsuperscript{23, 24} In the United States, the
overall prevalence of myopia in 12 to 17-year-olds has increased from 24.5% in 1971-1972 to 34.8% in 1999-2004. In Australia, it has been reported to be low as 1.4% in 6-year-olds, increasing to 5.1% in 12-year-olds. In the 12-year-old children of East Asian descent however, the prevalence of myopia was 41.6%.

In the Nepalese and Indian population, the prevalence of refractive error is also relatively low. The prevalence of myopia in Nepal was estimated at 1.2% in a large scale population-based survey of 5 to 15-year-old children. In rural India, the prevalence of myopia has been reported at a similarly low prevalence: 1.4% and 1.45%. In urban areas of India, the prevalence of myopia is higher at 7.4% and 3.16% but still relatively low.

In Malaysia, the prevalence of myopia was 9.8% in 7-year-olds, but this increased to 34.4% in 15-year-olds. Myopia was more strongly associated with Chinese compared to Malay ethnicity.

Children from Han Chinese descent tend to have the highest reported prevalence of myopia of any ethnic group, as evidenced by data from the Singaporean Chinese population, Taiwan, Hong Kong and mainland China. In Singapore, the prevalence is as high as 82.2% in children graduating from high school. This prevalence is higher in the Chinese Singaporeans compared to those of Malay or Indian descent. Interestingly, the children of Indian descent living in Singapore have a higher reported prevalence of myopia in this study compared to the surveys performed in India again suggesting the influence environment has on the development of myopia. In Taiwan, the prevalence of myopia in 6-year-olds is 12%, increasing to 76% at the age of 15. In Hong Kong, by the age of 17, more than 70% of children are myopic. In the Shunyi district of China, myopia was essentially absent in 5-year-old children, but increased to 36.7% in boys and 55.0% in girls.
with increasing age.\textsuperscript{21} In Yangxi County in China, the prevalence of myopia was 36.8% in 13-year-olds and this increased to 53.9% in the 17-year-old population.\textsuperscript{8}

The differences in prevalence of myopia across the surveys in different populations that have been performed to date suggest that race/ethnicity could be an associating factor. It remains difficult to assess however, the extent to which the differences can be attributed to genetic susceptibility and to environmental influences. It is possible that lifestyle differences may appear to be race/ethnicity related.

There was a clear association between urban schooling and higher prevalence of myopia. However, within the scope of this study, we are not able to provide an explanation as to why this association exists.

The major limitation of this study is that it was school rather than population-based. Drawing samples from children in schools is a potential source of bias. Many children may not be attending school and this may be underestimating the true prevalence of refractive error and visual impairment. Children with poor vision may even be precluded from attending school. Conversely, if near work and other aspects of schooling are causally related to the development of myopia, we may be overestimating the true prevalence. According to the UNESCO Institute of Statistics, the state school enrolment rate for primary education was 92% in 2009. This figure drops to 42% for secondary enrolment.\textsuperscript{28} Given the rate of enrolment which does not necessarily equate to attendance is less than 50%, the data from this study cannot necessarily be translated to the Cambodia population. Absenteeism rates are also high (approximately 25%), which is also a potential source of
bias. However, it would have been practically very difficult both in terms of time and expense to conduct a population-based survey with the same sample size.

There were a higher proportion of females included in the study compared to males, due to higher rates of absenteeism amongst boys. Given that myopia is associated with female gender, this may mean our data has been biased towards a higher prevalence of myopia compared to the general population. The latest census data from 2008 shows that in the 12-14 year old age group, there is a very similar distribution of males and females in Phnom Penh, and Kandal Provinces and Cambodia.

The actual prevalence of refractive error and that inferred by VA ≤ 6/12 differs because children can have refractive error with little or no visual deficit. Children with minor refractive error can often still see the 6/6 line on the visual acuity chart. We did not measure visual acuity past this point and it is probable that the normal population’s distance visual acuity was better than 6/6. It was also not always possible to prevent squinting/accommodation which would improve the presenting visual acuity.

For consistency with other studies, we defined myopia and hyperopia based on the spherical equivalent of the better eye. However, this includes children with low sphere and low cylinder who are not visually impaired, potentially overestimating the prevalence of refractive error.

Whilst the prevalence of refractive error was low in this survey, it is likely to be higher in older children. The age group of 12 to 14 was chosen because that is what the majority of children attending middle school are aged. Particularly in rural areas, children at the age of 15 are no longer regularly attending school. In our survey, there were a much lower
proportion of 14 year old children in urban schools again reflecting the shift towards lower retention rates in secondary schooling with increasing age.

We observed that many children who would have benefited from spectacles did not present with any highlighting a need for increased optical dispensing especially given that refractive error is the main cause of poor vision. Children from urban schools were happy to accept glasses. However, in rural schools, spectacle wear can be stigmatized. This is reflected in the fact that no children from rural schools had glasses. This also reflects the poor access to services in rural areas. However, given that the overall prevalence of refractive error is so low, it may be difficult to justify programs focused on this problem alone.

CONCLUSION

The prevalence of refractive error and in particular myopia is relatively low in Phnom Penh and Kandal Provinces of Cambodia. There is a definite association between urban schooling and myopia. Myopia is also associated with female gender and increasing age. Further studies are required to further elucidate the relationship between near work – both the number of hours and the distance this is performed at, outdoor work and the development of myopia. It would also be beneficial to have further population based data rather than just from schools.

The majority of children with refractive error did not have glasses in this survey highlighting the need for screening services, affordable optical dispensing and education regarding spectacle wear in Cambodia.
ACKNOWLEDGEMENTS

The authors would like to acknowledge The Fred Hollows Foundation and Sight For All Foundation who helped fund the survey, and thank all the Cambodian refractionists, ophthalmic nurses and ophthalmologists involved in helping to conduct the survey and examine the children.
REFERENCES


Chapter Four

A survey of severe visual impairment and blindness in children attending thirteen schools for the blind in Sri Lanka

Zoe Gao MBBS¹, James Muecke FRANZCO¹,²,³, Kapila Edussuriya MBBS DCEH(Hyd)⁴, Ranasiri Dayawansa MBBS, MD Ophth (SL)⁵, Michael Hammerton FRANZCO¹, Aimee Kong B. Optom¹, Saman Sennanayake MBBS, MS Ophth (SL), FRCS⁴, Tissa Senaratne MBBS, MS Ophth (SL)⁴, Nirosha Marasinghe DOT (SL)⁴, Dinesh Selva FRANZCO¹,².

¹ South Australian Institute of Ophthalmology, Adelaide, Australia;
² Discipline of Ophthalmology & Visual Sciences, University of Adelaide;
³ Department of Ophthalmology, Women’s and Children’s Hospital, Adelaide;
⁴ Centre for Sight, Teaching Hospital, Kandy, Sri Lanka;
⁵ Base Hospital Nawalapitiya, Sri Lanka

Ophthalmic Epidemiology; 2010: in press
STATEMENT OF AUTHORSHIP

A survey of severe visual impairment and blindness in children attending thirteen schools for the blind in Sri Lanka

*Ophthalmic Epidemiology; 2010: accepted paper*

**Zoe Gao** (Candidate) Master of Ophthalmology, Adelaide University
Data entry; analysis and interpretation of data, drafting of the manuscript, critical revision of the manuscript.
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**J Muecke**
Contributed to conception and design of survey; training and acquisition of data, critical revisions of manuscript; obtaining funding and supervision.

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K Edussuriya
Contributed to conception and design of survey; acquisition of data.

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R Dayawansa
Contributed to conception and design of the survey; acquisition of data.

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M Hammerton
Contributed to conception and design of the survey; acquisition of data.

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Signed .................................................................Date...13/09/2009

A Kong
Contributed to conception and design of the survey; training and acquisition of data.

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S Sennanayake
Contributed to conception and design of the survey; acquisition of data

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T Senaratne
Contributed to conception and design of the survey; acquisition of data.

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Signed ..........................Date...13/09/2009
N Marasinghe
Contributed to acquisition of data.

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D Selva
Contributed to conception and design of the study; critical revision of the manuscript for important intellectual content; obtaining funding and supervision.

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INTRODUCTION

The control of blindness in children is considered a high priority of the World Health Organization’s (WHO’s) “VISION 2020 – The Right to Sight” global initiative. Although childhood blindness is relatively uncommon, only 1.5 million of a worldwide total of 45 million blind people, it is a priority of Vision 2020 for several reasons. Firstly, the number of “blind years” in children is important because there is a lifetime of blindness ahead. This affects the child’s psychomotor and emotional development, education, opportunities for employment and earning potential, in addition to the impact on their family and community. Secondly, blind children have a higher mortality rate compared to their sighted counterparts. In developing countries, up to 60% of children are thought to die within a year of becoming blind. Finally, almost half of all childhood blindness cases, particularly in poor communities, are due to avoidable causes.

Of the 1.5 million blind children worldwide, 1 million live in Asia. There are now published surveys of schools for the blind looking at the major causes of childhood blindness in Asian countries such as Burma, Cambodia, India, Indonesia, Phillipines and Thailand. However, the prevalence and major causes of childhood blindness differ markedly between different regions, likely related to socioeconomic factors. Therefore it is important for individual national data to be collected in order to implement prevention or treatment initiatives.

Sri Lanka has 9 provinces and a population of over 21 million, 5 million of whom are children below 15 years of age. Sri Lanka’s health indicators are much better than those of other countries with similar economies largely because of the long tradition of universal primary education and a very good primary health care system. Measles immunisation
coverage is high, and there is a rubella immunisation program for all 12 year old school girls with a follow up visit at age 15.

The prevalence of blindness in children varies from approximately 0.2-0.3/1000 children in developed countries to 1.5/1000 children in developing countries. Although data are not available on the prevalence of blindness in Sri Lankan children, it is likely to be low (approximately 0.4/1000 children), the estimate being based on the association of blindness prevalence and under 5 mortality rates. There are, therefore, approximately 2000 children who are blind in Sri Lanka.

Previously, there have been difficulties in comparing the causes of visual loss in children because of the lack of a standardised reporting system that takes into account both anatomical and aetiological classifications. Therefore the International Centre for Eye Health in London, in collaboration with WHO, developed a standardised protocol – the WHO/PBL Eye Examination Record for Children with Blindness (ERCB). The ERCB form has been used throughout this survey.

There is one previously published survey by Eckstein et al who visited six schools for the blind in Sri Lanka in 1994. The purpose of the current study was to determine the causes of childhood blindness in Sri Lanka by identifying children with blindness and severe visual impairment (BL/SVI) from thirteen schools for the blind in the country and to compare our results with the 1994 study. The data are crucial to guide implementation of appropriate control measures and interventions.
METHODS

Children attending thirteen schools for the blind registered with the Ministry of Social Services in Sri Lanka were examined from October 2008 to October 2009. Written consent was obtained from each child’s parent or the principal of each school if the parents were not available. All children gave verbal assent.

Relevant information was collected from school staff, children and their parents (when present), and medical records. A brief history of onset of visual loss, family history, history of consanguinity, ethnic group and place of residence was taken and a detailed eye examination performed by a team of optometrists and ophthalmologists. Training of the Sri Lankan team was undertaken at the first school by the visiting Australian team of one optometrist and two ophthalmologists. The same members of the Sri Lankan team undertook the same component of the assessment at each of the subsequent schools to maintain consistency and reliability of data collection.

Each child’s presenting distance visual acuity was measured using a LogMAR LEA chart or by testing the ability to count fingers. Visual loss was classified according to the WHO categories of BL/SVI. Blindness (BL) is defined as a presenting VA <3/60 in the better eye, severe visual impairment (SVI) as VA <6/60 to 3/60 in the better eye, and visual impairment as VA <6/18 to 6/60 in the better eye. Functional vision was assessed by asking each child to navigate unassisted around two chairs placed one metre apart, their ability to recognise faces or see print. Visual fields were assessed by confrontation. The anterior segment was assessed by an ophthalmologist using slit lamp biomicroscopy. The posterior segment was evaluated by indirect or direct ophthalmoscopy with dilation of the pupil.
Children who had distance vision of better than NPL or were 'believed to have useful residual vision' (when formal testing of visual acuity was not possible but the child was believed to have sufficient residual vision for independent mobility, for making social contacts or for near vision), underwent refractive testing and low vision assessment by an optometrist. Pin-hole acuity was tested using a multiple pin-hole occluder and LEA chart at 3 metres, illuminated by natural sunlight or ambient room lighting. The chart was moved closer in logarithmic steps to measure VA <6/120 (3/60). Care was taken to ensure that background glare was minimised, (eg. sunlight through a window adjacent to the chart was blocked). Pin-hole acuity was not assessed in cases where it would obviously not improve vision (eg. complete central corneal opacification, macular or optic nerve pathology). Pin-hole acuity merely served as a gauge for potential VA improvement with refraction. A lack of improvement with pin-hole testing did not preclude assessing refraction, given the nature and severity of visual reduction and possible use of eccentric fixation.

Distance refraction was determined primarily by retinoscopy, using a trial frame and loose lenses. Refraction was subjectively refined by assessing visual improvement with +2D lenses, then bracketing with ±1D and ±0.5DS lenses for the spherical component. Astigmatism was assessed initially using a ±1 Jackson cross-cylinder (for VA ≤6/48), and refined using a ± 0.50 cross-cylinder (for VA>6/48). Cylinder axis was bracketed to within 5° steps and cylindrical power to within 0.50DC. Best-corrected visual acuity was tested with each eye separately, then together (unless NPL in the worse eye). Where refraction improved VA, distance spectacles were ordered and dispensed locally. When optical devices were prescribed, an onsite training of device usage was given with the demonstration extending to the class teacher of the child. The child and teacher were encouraged to communicate with the Low Vision trained Ophthalmic Technologist when ever possible.
Near vision was tested binocularly using 5mm shapes (square, circle, triangle), and a series of large (50mm), high contrast, matching shapes. Working distance was not specified in the near vision measurement, encouraging children to adopt their usual posture when attempting to read. Low vision aids were prescribed where appropriate.

After examination, the ophthalmologist recorded the major site of abnormality leading to visual loss for each eye and for the child using the WHO classification system in the Coding Instructions.\textsuperscript{17} When the major site of abnormality was different for the two eyes, or there were multiple abnormalities, the most preventable or treatable abnormality was selected. If neither eye had preventable or treatable abnormalities, the abnormality that occurred most recently was selected. If it was not known which abnormality occurred most recently, the eye with better vision was selected. The main aetiology of visual loss was recorded for each eye and for the child. When the aetiology was different for each eye, the aetiology selected for the child was that of the major site of abnormality. The need for optical, surgical or medical interventions was recorded and the visual prognosis assessed. All data were recorded using the WHO/PBL ERCB form and entered into an Excel database.\textsuperscript{17}

**Ethics approval**

Permission to visit the schools was granted by each principal. Ethics approval was obtained from the Faculty of Medicine, University Of Peradenya Ethical Review Committee in Sri Lanka and the Royal Adelaide Hospital Research Ethics Committee.
RESULTS

A total of 235 children were examined at thirteen schools. All the blind schools registered with the Ministry of Social Services were visited except one school due to the political situation at the time. Of the 235 children examined, only 206 were eligible for this study – the remainder either being too old or not visually impaired. Of the 206 children, 56.8% were male and 43.2% female. The age of the children ranged from 3 to 15 years with 65% between 10 and 15. 172 children (83.5%) were blind, 19 were severely visual impaired and 14 were visually impaired (see Table 2.1).

<table>
<thead>
<tr>
<th>WHO category</th>
<th>Vision in better eye</th>
<th>Number</th>
<th>%</th>
</tr>
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<tbody>
<tr>
<td>Visual impairment</td>
<td>&lt;6/18-6/60</td>
<td>14</td>
<td>6.8</td>
</tr>
<tr>
<td>Severe visual impairment</td>
<td>&lt;6/60-3/60</td>
<td>19</td>
<td>9.2</td>
</tr>
<tr>
<td>Blind</td>
<td>&lt;3/60</td>
<td>172</td>
<td>83.5</td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>206</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2.1. Visual Acuity in all 206 children

Among the 14 children who were visually impaired, there were 2 cases of amblyopia – one due to delayed cataract surgery and the second due to high myopia, 2 cases of uveal coloboma, 3 cases of refractive error, 3 retinal dystrophies, and one each of aphakia, cataract, idiopathic nystagmus and microphthalmos. All subsequent analyses are for the 192 children who were blind or had severe visual impairment.

The majority of the children examined were of Singhalese ethnic origin (162, 84.4%), had no associated physical or mental disabilities (166, 86.5%), and had visual loss from birth
(148, 77.1%) (see Table 2.2 for demographic data). Family history of eye disease was found in 38 cases (19.8%), with the majority of these having cataract (7, 18.4%) and retinal dystrophy (18, 47.4%). A history of consanguineous marriage was present in 22 cases (11.5%) and accounted for 7 (18.4%) of the children with a positive family history of eye disease.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ethnic Group</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Singhala</td>
<td>162</td>
<td>84.4</td>
</tr>
<tr>
<td>Tamil</td>
<td>19</td>
<td>9.9</td>
</tr>
<tr>
<td>Muslim</td>
<td>11</td>
<td>5.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>192</td>
<td>100</td>
</tr>
<tr>
<td><strong>Age at onset of visual loss</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Since birth</td>
<td>148</td>
<td>77.1</td>
</tr>
<tr>
<td>First year of life</td>
<td>15</td>
<td>7.8</td>
</tr>
<tr>
<td>Aged 1-15 years</td>
<td>24</td>
<td>12.5</td>
</tr>
<tr>
<td>Unknown</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>192</td>
<td>100</td>
</tr>
<tr>
<td><strong>Family history</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>38</td>
<td>19.8</td>
</tr>
<tr>
<td>No</td>
<td>149</td>
<td>77.6</td>
</tr>
<tr>
<td>Unknown</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>192</td>
<td>100</td>
</tr>
<tr>
<td><strong>Consanguinity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>22</td>
<td>11.5</td>
</tr>
<tr>
<td>No</td>
<td>100</td>
<td>52.0</td>
</tr>
<tr>
<td>Unknown</td>
<td>70</td>
<td>36.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>192</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2.2. Demographic details

The majority of children had no previous eye surgery (158, 82.3%). Of those who did have surgery, the majority were for cataracts (19, 50%). Two of these cases were combined with
a trabeculectomy and there was one case of isolated glaucoma surgery. There were four corneal grafts, one of which was combined with cataract surgery, two enucleations, three examinations under anaesthesia, one excision of a dermoid and the remainder had multiple surgeries or surgeries which were unspecified or unknown.

**Anatomical Site of Abnormality - Table 2.3**

The major anatomical sites of abnormality were the retina (35.9%), whole globe (22.4%), lens (10.9%) and optic nerve (10.9%). Retinal dystrophy was the commonest abnormality of the retina followed by retinopathy of prematurity. Of the 43 children with whole globe abnormalities, 24 had congenital abnormalities such as anophthalmos or microphthalmos. Cataract only made up 13 cases in total (6.8%).
<table>
<thead>
<tr>
<th>Site of abnormality</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Whole globe</strong></td>
<td>43</td>
<td>22.4</td>
</tr>
<tr>
<td>Phthisis</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>Anophthalmos</td>
<td>8</td>
<td>4.2</td>
</tr>
<tr>
<td>Microphthalmos</td>
<td>16</td>
<td>8.3</td>
</tr>
<tr>
<td>Buphthalmos</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>Glaucoma</td>
<td>6</td>
<td>3.1</td>
</tr>
<tr>
<td>Removed</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Disorganised</td>
<td>7</td>
<td>3.7</td>
</tr>
<tr>
<td><strong>Cornea</strong></td>
<td>15</td>
<td>7.8</td>
</tr>
<tr>
<td>Scar</td>
<td>9</td>
<td>4.7</td>
</tr>
<tr>
<td>Other opacity</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Lens</strong></td>
<td>21</td>
<td>10.9</td>
</tr>
<tr>
<td>Cataract</td>
<td>13</td>
<td>6.8</td>
</tr>
<tr>
<td>Aphakia</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Uvea</strong></td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Aniridia</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>Coloboma</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Uveitis</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Retina</strong></td>
<td>69</td>
<td>35.9</td>
</tr>
<tr>
<td>Dystrophy</td>
<td>40</td>
<td>20.8</td>
</tr>
<tr>
<td>Albinism</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>ROP</td>
<td>23</td>
<td>12.0</td>
</tr>
<tr>
<td>Retinoblastoma</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Optic nerve</strong></td>
<td>21</td>
<td>10.9</td>
</tr>
<tr>
<td>Atrophy</td>
<td>16</td>
<td>8.3</td>
</tr>
<tr>
<td>Hypoplasia</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Refractive error</strong></td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Amblyopia</strong></td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Cortical blindness</strong></td>
<td>6</td>
<td>3.1</td>
</tr>
<tr>
<td>Idiopathic nystagmus</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Unknown</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Other not listed</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>192</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2.3. Anatomical site of abnormality
Aetiological classification of visual loss - Table 2.4

Hereditary factors were the most common aetiology of blindness, accounting for 37.5% (72) of the cases, where there was a positive family history of another similarly-affected individual or a well-recognized or proven genetic abnormality in the absence of family history, according to WHO/PBL Examination Record Coding Instructions.

In 43.8% of cases the underlying aetiology could not be determined. Of these, the abnormality had been present since birth in 34.4% (66). Cataract was responsible for 5 cases and glaucoma 4. Perinatal and neonatal disorders were the third most common aetiology of blindness, accounting for 14.1% (27) of the cases. Retinopathy of prematurity was the predominant neonatal factor. There were no definite cases of vitamin A deficiency.
### Table 2.4. Aetiological categories of visual loss

<table>
<thead>
<tr>
<th>Aetiological Category</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hereditary</strong></td>
<td></td>
<td>37.5</td>
</tr>
<tr>
<td>Auto dominant</td>
<td>17</td>
<td>8.9</td>
</tr>
<tr>
<td>Auto recessive</td>
<td>8</td>
<td>4.2</td>
</tr>
<tr>
<td>Cannot Specify</td>
<td>47</td>
<td>24.5</td>
</tr>
<tr>
<td><strong>Intrauterine</strong></td>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>Rubella</td>
<td>4</td>
<td>2.1</td>
</tr>
<tr>
<td><strong>Perinatal/Neonatal</strong></td>
<td></td>
<td>14.0</td>
</tr>
<tr>
<td>Cerebral hypoxia/injury</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>ROP</td>
<td>24</td>
<td>12.5</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Postnatal/Childhood</strong></td>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td>Trauma</td>
<td>4</td>
<td>2.1</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>Unknown Aetiology</strong></td>
<td></td>
<td>43.8</td>
</tr>
<tr>
<td>Cataract</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Glaucoma/Buphthalmos</td>
<td>4</td>
<td>2.1</td>
</tr>
<tr>
<td>Retinoblastoma, no FH</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>Abnormality since birth</td>
<td>66</td>
<td>34.4</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>192</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Overall, 34.9% (67 cases) of BL/SVI were potentially avoidable: 6.8% (13 cases) were preventable and 28.3% (54 cases) were treatable. Retinopathy of prematurity was by far the largest group of avoidable causes making up 24 cases.
### Table 2.5. Avoidable causes of blindness

![Avoidable causes of blindness table]

<table>
<thead>
<tr>
<th>Causes</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preventable causes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trauma</td>
<td>4</td>
<td>2.1</td>
</tr>
<tr>
<td>Rubella</td>
<td>4</td>
<td>2.1</td>
</tr>
<tr>
<td>Cerebral hypoxia/injury</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>Amblyopia</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Treatable causes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perinatal meningitis</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>Cataract</td>
<td>13</td>
<td>6.8</td>
</tr>
<tr>
<td>Lens other</td>
<td>3</td>
<td>1.6</td>
</tr>
<tr>
<td>Glaucoma/buphthalmos</td>
<td>8</td>
<td>4.2</td>
</tr>
<tr>
<td>Uveitis</td>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>ROP</td>
<td>24</td>
<td>12.5</td>
</tr>
<tr>
<td>Retinal detachment</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>Refractive error</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>67</td>
<td>34.9</td>
</tr>
</tbody>
</table>

No children had a pair of spectacles or LVAs at presentation. A few children had been prescribed glasses but either were not using them regularly, or they were broken. This was because they had not been educated in their use. 91 children were believed to have useful vision (45.1%). The majority required no optical services (128, 66.7%), however 19 children (9.9%) required both spectacles and LVAs, 18 children required LVAs only and 27 required spectacles only for distance correction. The presenting vision and causes of visual loss in the better eye for children prescribed optical devices have been tabulated in tables 2.6 and 2.7.
Table 2.6. Presenting vision in better eye for children prescribed optical devices

<table>
<thead>
<tr>
<th>Presenting vision in better eye</th>
<th>Spectacles (N)</th>
<th>LVA (N)</th>
<th>Both (N)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6/18-6/60</td>
<td>6</td>
<td>3</td>
<td>5</td>
<td>21.9</td>
</tr>
<tr>
<td>&lt; 6/60-3/60</td>
<td>7</td>
<td>1</td>
<td>6</td>
<td>21.9</td>
</tr>
<tr>
<td>&lt;3/60-PL</td>
<td>14</td>
<td>14</td>
<td>8</td>
<td>56.2</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>18</td>
<td>19</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2.7. Causes of visual loss for children prescribed optical devices

<table>
<thead>
<tr>
<th>Cause of visual loss in better eye</th>
<th>Spectacles (N)</th>
<th>LVA (N)</th>
<th>Both (N)</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retinal disease</td>
<td>8</td>
<td>5</td>
<td>11</td>
<td>37.5</td>
</tr>
<tr>
<td>Optic nerve disease</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>7.8</td>
</tr>
<tr>
<td>Albinism</td>
<td></td>
<td></td>
<td>1</td>
<td>1.6</td>
</tr>
<tr>
<td>Cataract/Lens</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>18.8</td>
</tr>
<tr>
<td>Corneal disease</td>
<td>2</td>
<td>1</td>
<td></td>
<td>4.7</td>
</tr>
<tr>
<td>Nystagmus</td>
<td>1</td>
<td></td>
<td></td>
<td>1.6</td>
</tr>
<tr>
<td>Coloboma</td>
<td></td>
<td></td>
<td>3</td>
<td>4.7</td>
</tr>
<tr>
<td>Unknown</td>
<td></td>
<td></td>
<td>2</td>
<td>4.7</td>
</tr>
</tbody>
</table>

The majority of children required no further medical attention (185, 96.4%). Fourteen children required cataract surgery and 3 required YAG capulotomies for posterior capsule opacification. The remainder required non-surgical treatments. The majority of the cases were likely to remain stable (168, 87.5%). The 17 cases that could be improved and the 7 cases that were likely to deteriorate were referred to the local ophthalmologist.
A change in schooling was recommended for 11 children (after consultation with the principal of the respective school) in whom visual acuity could be improved to better than 6/18 following refraction and prescription of spectacles. Another 4 were to consider changing to an integrated school after surgery and 6 children were recommended changing to a school for children with multiple disabilities.

DISCUSSION

Even though there are an estimated 2000 blind children in Sri Lanka, this survey only looks at the major causes of SVI/BL in less than 10% of those children. However, because of the low prevalence of blindness in children, very large population-based surveys would be required to obtain accurate population-based estimates of the major causes. This is not only expensive but also logistically and technically difficult. By surveying only the schools for the blind using a standard protocol, the study team was able to survey a large number of children in a relatively short period of time. Data from schools for the blind have been shown to be comparable to that obtained from community-based studies. However, this survey excludes all pre-school children and infants. In addition, there is selection bias due to the fact that many schools are located in urban settings and therefore may exclude rural or poorer families. Children with multiple disabilities are often refused entry to schools for the blind thereby under-representing visual loss associated with other disabilities.

The data show a slight preponderance of males over females (56.8% vs 43.2%), an observation seen in other similar studies, and which is likely to be a reflection of the social bias towards education of males rather than gender differences in causes of blindness. There is perhaps not as large a difference between the gender groups.
compared to other Asian countries because of the long tradition of free, universal primary education and high literacy rates amongst males and females in Sri Lanka. Additionally, males are more likely than females to have hereditary causes of blindness due to their greater risk of X-linked conditions.

Of children in this study with BL/SVI, the proportion of lens pathology was much lower (10.9%) in comparison to many of the neighbouring countries in South East Asia. For example, in Myanmar lens pathology made up 14.4% of childhood blindness\(^6\), in Indonesia 14.6%\(^{12}\), Thailand 16.9%\(^{13}\), Philippines 9.7-16.8%\(^{13}\) and even higher levels in Cambodia (27.4%)\(^7\), Malaysia (22.3%)\(^{23}\), Mongolia (34%)\(^{20}\), and Bangladesh (32.5%)\(^{24}\).

Corneal scarring only made up 4.7% of cases, which is a marked difference to countries such as Myanmar (49.5%)\(^6\), India (22.2-26.4%)\(^{8,10,11}\) Indonesia (16.0%)\(^{12}\), Thailand (12.3%)\(^{13}\), rural Philippines (42.9-54.8%)\(^{13}\) and Cambodia (17.7%)\(^7\) where the cornea was a major site of abnormality. Whilst the cause for such a high proportion of corneal blindness in these countries was mainly attributed to measles keratitis and vitamin A deficiency, there were no definite cases of vitamin A deficiency or measles in the Sri Lankan data. This is likely due to the fact that there are well established primary health care strategies in place for preventing measles and vitamin A deficiency.

The cause of BL/SVI was unknown in the majority of cases (43.8%). This is similar to the 1994 survey (56.2%)\(^{18}\). In most of these cases, the abnormality had been present since birth. The large proportion of undetermined aetiology is consistent with results from other studies using similar methods and reflects the inadequate medical notes, the limited scope for investigation, and the inability to obtain a medical history from or examine family members. Unknown causes also predominated in the studies from schools for the blind in
Malaysia, Myanmar, Cambodia, India, Indonesia, Thailand, Bangladesh and China. 6-13, 21-24

The percentage of hereditary disease accounting for BL/SVI (37.5%) is again similar to the 1994 survey (35%). 18 The majority of genetic disease was unknown or could not be specified. The rate of consanguinity of 11.5% found in this study may attribute to some of these hereditary cases. The proportion of hereditary disease in this study is similar to studies from Indonesia (41.5%)12, India (up to 34.8%)8-11, Malaysia (29.5%)23, China21 (30.7%) and Mongolia20 (27%). Other neighbouring regions with lower hereditary diseases include Myanmar6 (11.9%), Thailand13 (13.8%) and Philippines13 (17.8%).

Perinatal/Neonatal factors were the third commonest cause of BL/SVI (14.1%), the majority of these being due to retinopathy of prematurity (ROP). This is substantially higher than was previously reported in the 1994 survey where there were no cases of ROP.18 This is reflecting the change seen in other middle income countries (such as in Latin America) where neonatal intensive case is becoming more developed but the introduction of screening for ROP has not yet been established.2

Apart from the high proportion of blindness secondary to ROP, the data distribution shows a similar pattern to developed countries where the majority of BL/SVI is congenital or occurs within the first year of life.16 There are some differences, however, in the pattern of disease when compared to developed countries. Firstly, lesions of the higher visual pathways predominate in industrialised countries, which is not the case in this Sri Lankan data. This may be because the incidence is low in Sri Lanka, or that mortality rates are higher, or that these children are significantly disabled and hence not receiving education. Secondly, there is a high proportion of blindness due to microphthalmos and anophthalmos of unknown aetiology. Whilst hereditary factors are likely to be responsible for some
Avoidable causes of BL/SVI were seen in 34.9% of children. Four (2%) of the preventable cases were due to rubella despite a successful immunisation program for 12 year old girls. These cases may however, represent children that were born prior to the implementation of the National Immunisation Program in 1996.

On review of the data from this survey, it is clear that primary health care is well established in Sri Lanka. However, there is certainly a need for improved optometric and low vision services given that one third of children required optical correction or low-vision aids. Low vision services are particularly important for the large number of children with incurable visual loss (for example due to retinal dystrophy) with vision <6/60 but better than 1/60. These children could greatly benefit from assessment by a team consisting of a paediatric ophthalmologist, an optometrist with low vision experience, and a low vision therapist. The therapist is important for training and motivating the child in the use of LVAs in order to achieve maximum benefit. Currently, a national program is in place and twelve low vision clinics covering the whole country have been established.

There is also a definite need for specialised tertiary level paediatric eye care services. VISION2020 advocates one specialist children’s eye care centre for every 10 million population,¹ which means Sri Lanka should ideally have two such centres. To adequately treat congenital cataracts, it is imperative that the disease is detected early and treated prior to the development of amblyopia, and once treated, regular long term follow up is required in addition to the provision of aphakic spectacles. The Sri Lankan College of
Ophthalmologists and the College of Paediatricians of Sri Lanka are aware that ROP has become a problem and are developing guidelines for screening and treatment.

CONCLUSION

Just over one third of the children in schools for the blind in Sri Lanka had potentially avoidable causes of BL/SVI, with retinopathy of prematurity making up the largest proportion of these cases. Vision could also be improved in one third of children with the provision of spectacles and LVAs. The data support the need to develop specialised paediatric ophthalmic services, particularly in the face of advancing neonatal life support in Sri Lanka, and to provide optometric and low vision services.
REFERENCES


CONCLUSION

Results

One of the most important findings from the Sri Lankan survey of thirteen schools for the blind was that retinopathy of prematurity (ROP) is an emerging avoidable cause of blindness and severe visual impairment as neonatal resuscitation becomes more advanced. It highlights the need for specialised paediatric ophthalmic services to screen for and treat ROP. Interestingly, corneal disease and cataract were not major causes of blindness unlike many of Sri Lanka's surrounding South East Asian neighbours. In addition, the vision could be improved in one third of the children with either spectacles, low vision aids or both. These results have been presented to the Sri Lankan government so that appropriate management strategies can be implemented.

The Cambodian refractive error survey found a relatively low overall rate of refractive error in the 12 to 14 year old population compared to other Asian countries such as China. There was a significantly higher prevalence of myopia in the urban compared to the rural population group. Myopia was also associated with female gender and increasing age. These findings are consistent with previous refractive error surveys. The majority of the children, particularly in rural areas did not have any spectacle correction for their refractive error highlighting the need for increased services for spectacle prescription and dispensing.
Further research directions

It would be beneficial to undertake a further school for the blind survey in Sri Lanka in several years to monitor the efficacy of public health strategies implemented targeted towards managing ROP and delivering refractive services where needed. It is also important to determine if there are new emerging avoidable causes of blindness. Just as our survey identified ROP, which was not a problem when a previous survey had been performed in 1994, it is likely that the aetiology of childhood blindness and severe visual impairment will change with time.

Further data on refractive error in children in Cambodia including those not at school would be beneficial. Further research into the aetiology and pathogenesis of myopia is required to determine the exact cause for the difference in the prevalence of myopia between urban and rural population groups. Whilst there is some compelling evidence to suggest near work is associated with the development of myopia, results have not always been consistent. Some surveys have suggested it may not be near work that is associated with myopia but rather outdoor activities which are protective. Further large scale surveys with reliable questionnaires to determine an accurate estimate of near and outdoor activities are required to answer this question. However, such research would not be appropriate in a country such as Cambodia given the low prevalence of refractive error.